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UCRL-PROC-212188

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May 12, 2005

TIGRESS Workshop
Guelph, Canada
February 21, 2005 through February 22, 2005

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Nuclear Structure of Radioactive Neutron-Rich Nuclei with 4π Detector Arrays

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In-beam studies of γ-ray spectroscopy of radioactive neutron-rich nuclei using the 4π TIGRESS array at TRIUMF requires a "tag" to improve the selectivity of the detected γ rays in the high γ-ray background produced by radioactive beams and the need for Doppler-shift correction. We propose development of two types of large solid angle auxiliary charged particle detectors to be used in conjunction with TRIGRESS in order to provide the required tag.

The initial phase of detector development will focus on research involving light-mass radioactive beams with $Z \leq 20$. Gas avalanche detectors, such as CHICO, are not the ideal detector for lighter ions. Therefore, a new detector system, called Bambino, is being developed that is based on commercially available CD type position-sensitive silicon detectors. Three CD-S2 detectors, with a thickness of 140 μm, have been ordered from Micron Semiconductor Ltd. A split spherical target chamber will be built in Rochester to accommodate two of those CD detectors in both forward and backward directions. These detectors will be placed 3 cm from the target, providing an angular coverage from 20.1^o to 49.4^o for the forward hemisphere and from 130.6^o to 159.9^o for the backward hemisphere. The detectors will us ten 8-channels preamplifiers, from Swan Research, that will be mechanically mounted on both the entrance and exit beam pipes. The work on both the internal and external cables connecting the detectors to the preamplifiers, vacuum feedthrough etc. is in progress. In addition, a vacuum chamber has been ordered from Kurt J. Lesker Company for testing these detectors. Bambino should be ready by the spring 2006.

The second phase will involve the development of a next generation CHICO-like gas avalanche detector for experiments involving heavier radioactive beams. CHICO, a highly segmented parallel-plate avalanche counter, has proven to be very successful when used in conjunction with Gammasphere [1-2]. It has an angular coverage of 2.8π sr and an angular resolution of 1^o in θ and 4.6^o in ϕ in addition to a time resolution of 500 ps. The proposed new avalanche detector will have an improved position resolution that matches the (2 mm) achieved by TIGRESS. This longer-term detector development project is predicated on future funding and we actively seek collaborators. Such a detector system, used in conjunction with a thin target, allows the detection of both scattered and recoiling nuclei in kinematic coincidence providing a unique tag for the detected γ rays and at the same time providing sufficient information for the proper Doppler-shift corrections. This detector system can accommodate many types of experiments involving (quasi) two-body kinematics, such as Coulomb excitation [2-7], few-nucleon transfer reactions [8-10], deep-inelastic reactions [11-16], and spontaneous fissions [1] or fusion-fission reactions [17-20] we have carried out in the past.

The initial phase of proposed experiments will be to study, by Coulomb excitation, the issue of the “island of inversion” for the Mg isotopes in the $N \approx 20$ region. The $B(E2)$ values for the first 2^+ states of ^{30,32,34}Mg have been measured using intermediate-energy Coulomb excitation at projectile fragmentation facilities. The $B(E2)$ value for ^{30}Mg also was measured recently via conventional Coulomb excitation at the CERN REX-ISOLDE facility. The spread in measured $B(E2)$’s of up to a factor of two is insufficient to distinguish among various shell model predictions. Obviously, more precise measurements are necessary to ascertain how well the shell model can predict the properties of neutron-rich nuclei. An accuracy about 5% for the measured B(E2) can be achieved assuming a three-day beam time with an intensity about 3×10^4 p/s of ^{32}Mg on a 3 mg/cm^2 ^{208}Pb target at E_{lab}=115 MeV. A measure of the shape or the static quadrupole moment of this nucleus, in addition to the B(E2) value, would be possible if the beam intensity were above 10^6 p/s.

When heavier radioactive beams become available at the ISAC-II facility, it will open new research opportunities for exploring the nuclear structure of neutron rich nuclei, including the evolution with isospin of two-phonon vibrations, prolate-to-oblate shape transitions, octupole deformation and neutron pairing.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory and Los Alamos National Laboratory under contracts no. W-7405-ENG-48 and W-7405-ENG-36, respectively. The work performed at University of Rochester was supported by NSF.

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